Lecture 23: April 20, 2004

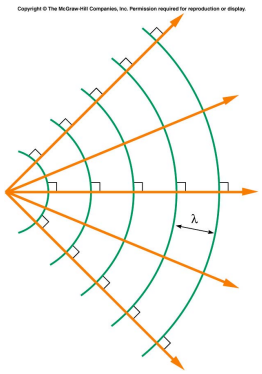
Know:

1. The law of reflection.
2. The law of refraction.
3. The difference between a real and a virtual image.
4. How a mirror forms an image.
5. How a lens focus light.
6. The difference between a converging and a diverging lens.

Understand:

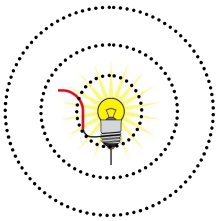
1. How to trace the principal rays when a mirror reflects them.
2. How to trace the principal rays when they travel through a lens
3. How to determine the location of an image formed by a mirror & lens
4. How to calculate the magnification of a mirror and a lens.
5. How the law of refraction explains the phenomena of total internal reflection
6. How lenses are used to make optical devices such as microscopes and telescopes

Light Rays

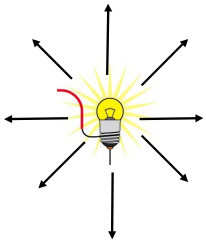


- Light Rays are electromagnetic waves that can be seen by humans (frequency~4-7x10^{14} hertz)
- To represent light waves we use:
  - Wavefronts that is concentric spherical shells (like balloons) separated by the one wavelength distance (analogous to water waves)
  - Light rays that is a arrows in the direction the light is travelling

Example: Light Bulb Waves

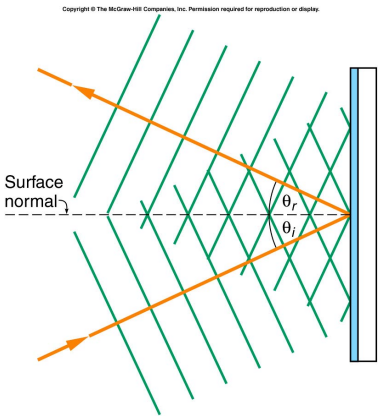


Light fronts



Light rays

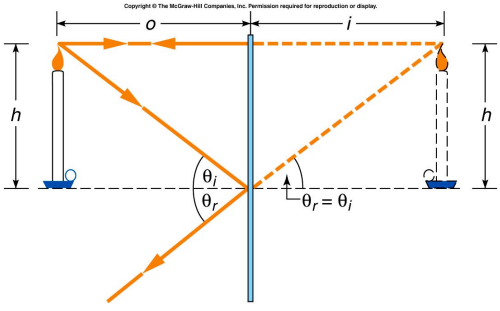
Law of Reflection or Light Reflection in a Mirror



Plane light waves approaching a mirror at an angle travel with the same speed both before and after striking the mirror.

The angle of reflection equals the angle of incidence

Image Formation on a Mirror



- Reflected Light Rays from the top of the candle appear to be coming from a point behind the mirror, called virtual image since the light never actually passes through the image location.

Refraction

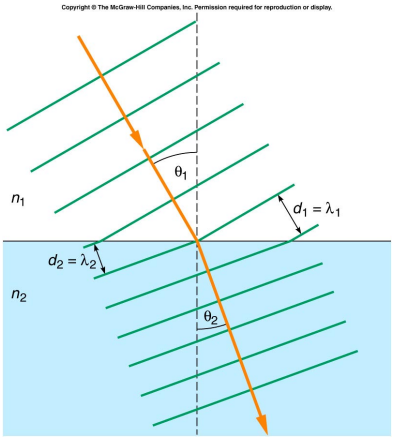
- When light travels in glass or water it has a smaller speed. The distance between wavefronts will be smaller (smaller wavelength).
- The velocity of light in a medium can be calculated using the index of refraction n as:

$$v = \frac{c}{n}$$

Speed in medium= $\frac{\text{Speed of light}}{\text{Index of refraction}}$

where c = 3x10^8 m/s is the speed of light in vacuum (and in air)

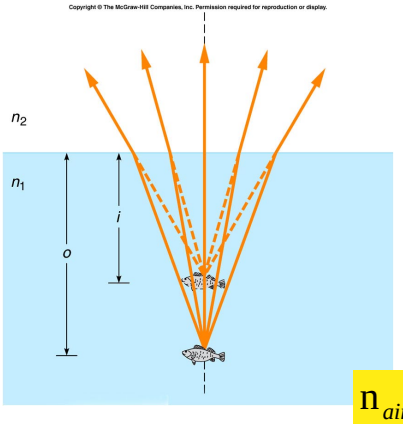
Law of Refraction



- Shorter wavelength in the glass
- The light rays bend as they pass from air into the glass.
- For small angles we can write

$$n_1 \theta_1 = n_2 \theta_2$$

Underwater Objects

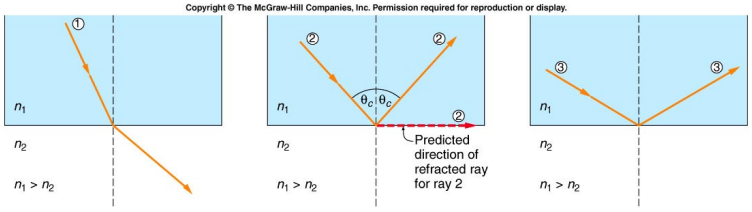


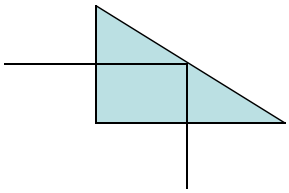
- Bending of lightwaves is responsible for deceptive appearances
- Apparent distance *i* is closer to the surface than the real object distance *o:*

$$i = o \frac{n_{air}}{n_{water}}$$

$n_{air} = 1 \qquad n_{water} = 1.33$

Total Internal Reflection

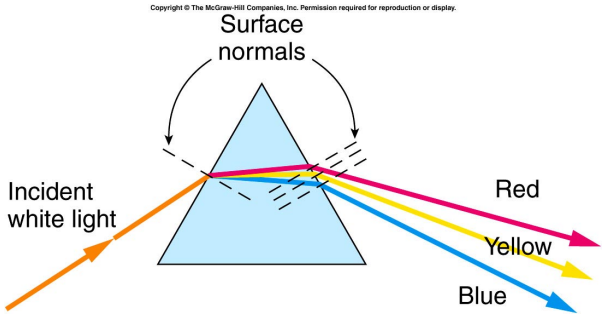




Optical fibers

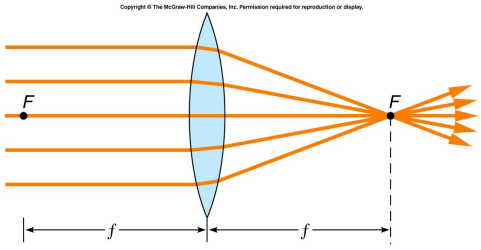
How do prisms bend light and what is dispersion?

Fig. 17.13



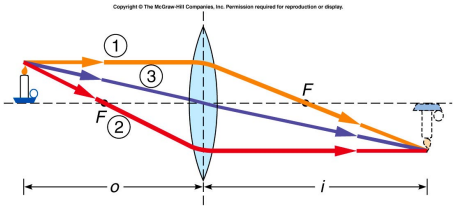
Variation of index of refraction *n* with wavelength l is called dispersion

Convex Lenses (I)



- Lenses bend light rays according to the law of refraction
- Convex lenses (also called positive converging lens) bend parallel light rays toward the axis so that they all pass through the focal point F located at a distance *f* called focal length from the lens axis
- More sharply curved lenses have a shorter focal length

Convex Lens (II)

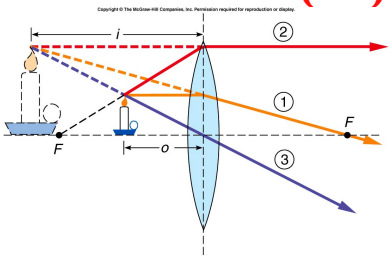


$$\frac{1}{o} + \frac{1}{i} = \frac{1}{f}$$

$$magnification = -\frac{i}{o}$$

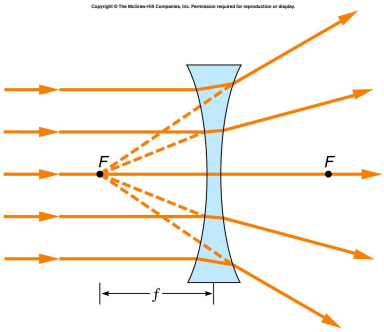
- Three rays can be traced to locate the image (one parallel to the lens axis, one going through the center, one going through the near-side focal point)
- If the object is farther than the focal point than it will have an inverted real image on the opposite side of the lens

Convex Lens (III)



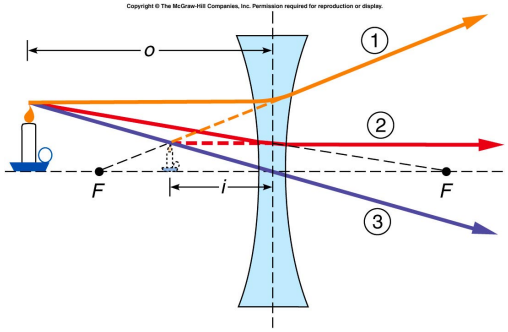
- Three rays can be traced to locate the image (one parallel to the lens axis, one going through the center, one going through the near-side focal point)
- If the object is closer than the focal point than it will have a magnified virtual image on the same side of the lens

Concave Lenses (I)



- Light Rays traveling parallel to the lens axis are bent away so they appear to diverge from a common focal point F

Concave Lenses (II)



- Real object image is always reduced size and virtual